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The Hydro-ecology of Everyday Life: Assessing the Social and Environmental Determinants of Water Use in the Portland Region

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The Hydro-Ecology of Everyday Life:

Assessing the social and environmental determinants of water use in the Portland region

Vivek Shandas
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System Science Seminar, PSU, May 2010

How many Olympic size swimming pools does it take to quench the thirst of people living in the Portland metropolitan region for one day?

(Hint: One Olympic Size Swimming Pool contains: 2,500 m³ or 660K Gallons)

Almost 408!

At current rates of population growth and water use, by 2040 the region will consume the amount of water equivalent to Crater Lake

Water as the New Carbon?

“Water flows uphill towards money.”

– Marc Reisner, *Cadillac Desert*, 1986

- **Headline news:**

- “Water Shortages: Atlanta's Cup Nearly Runneth Out” -- *The NY Times* (2008)

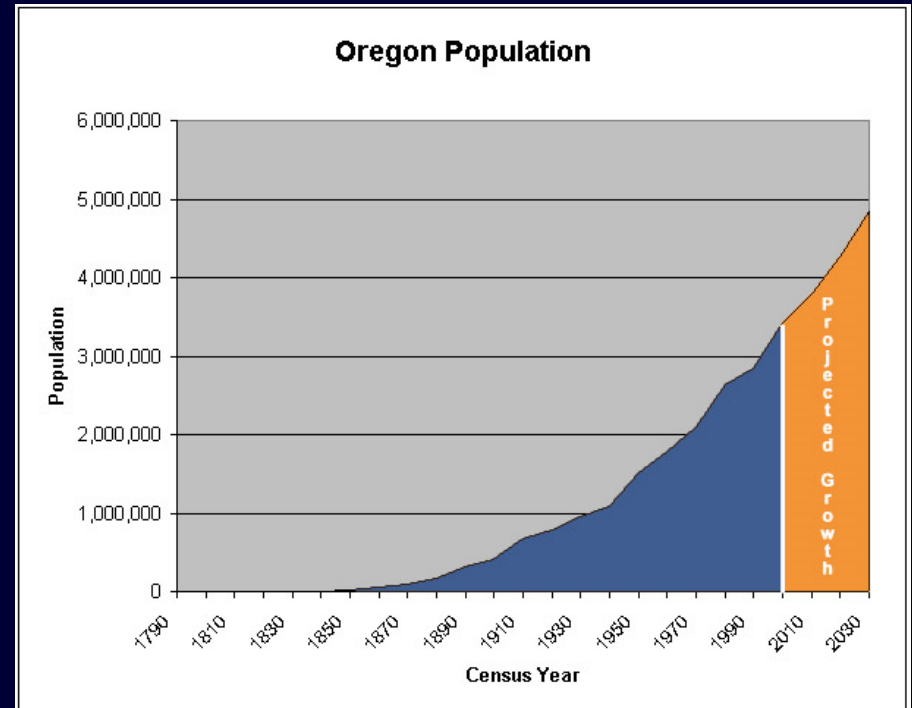
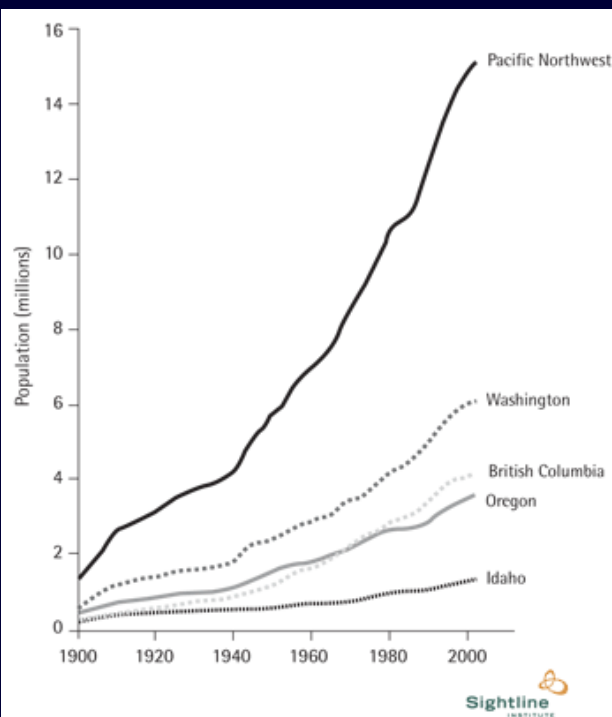
- “Large companies not prepared for water shortage”
– *Bussiness Week* (2007)

- *Water rationing is possible this summer: Light snowpack, low reservoirs creates shortages in California.* – *LA Times* (2007)

- “Shortage of water brings restrictions” – *St.Petersburg* (2006)

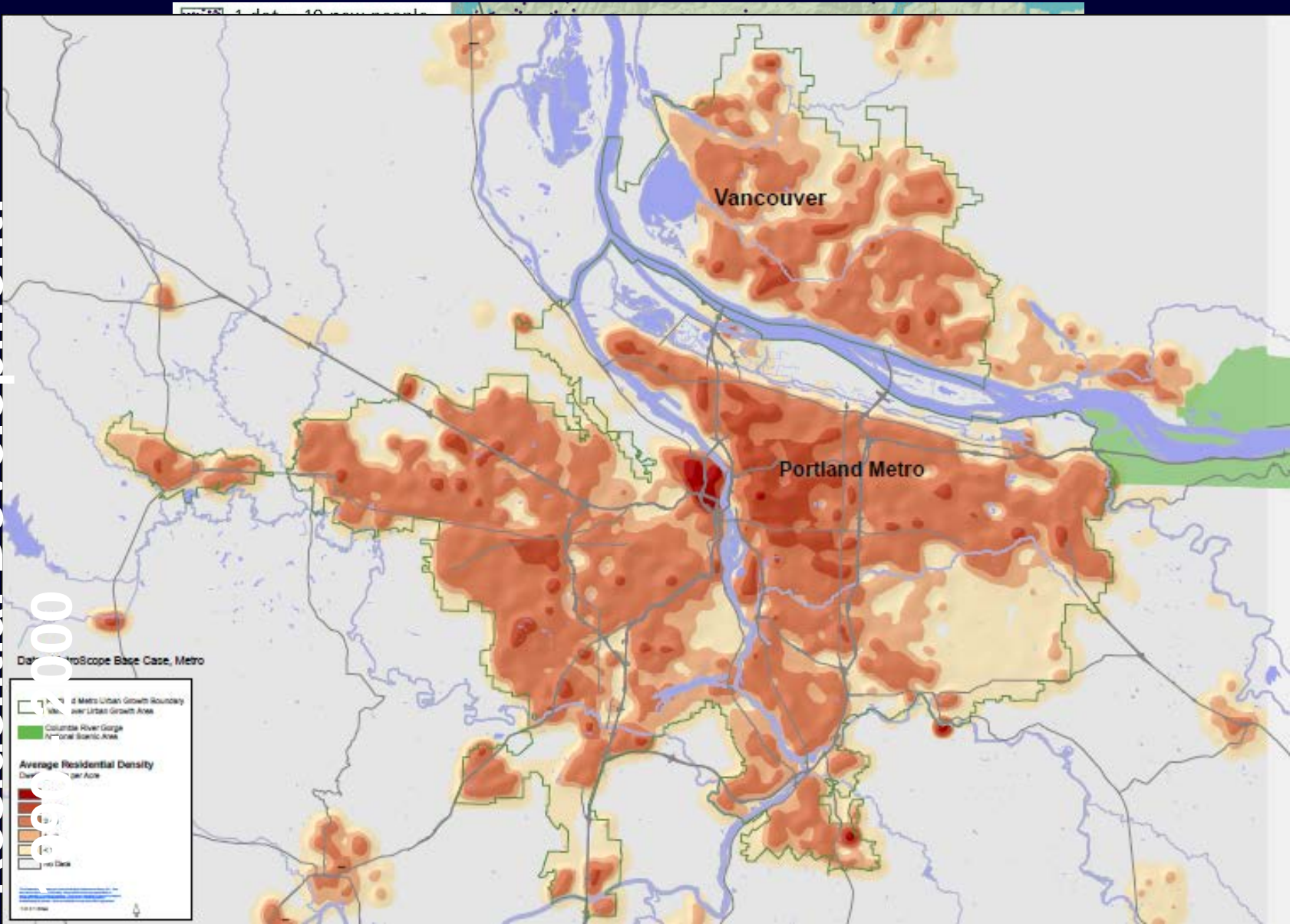
Background – the Problem

- Population growth in the NW
- Climate destabilization and variability – supply side focus with limited empirical evidence on demand measures
- Limited coordination between land use planning and water resource management
 - Water demand management without info on the impact of land use patterns
 - Land use planning without consideration of water demand



Residential Land Use

Residential Dwelling Density:
2005
Residential Development:



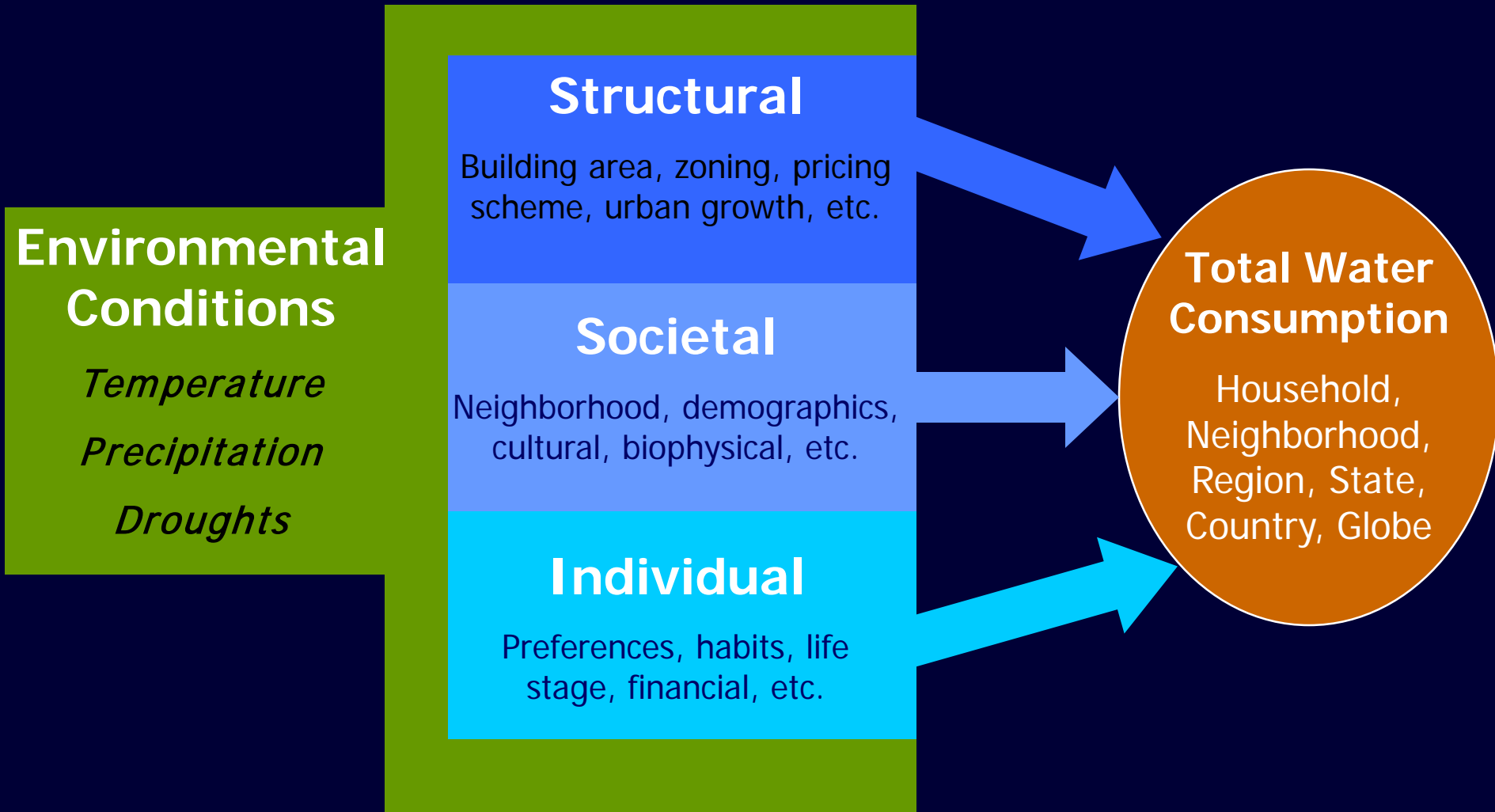
Study Objectives

- Assess the role of urban form in water use
- Investigate what factors explain patterns of water use (demand focus)
- Examine the effects of temperature change on water use



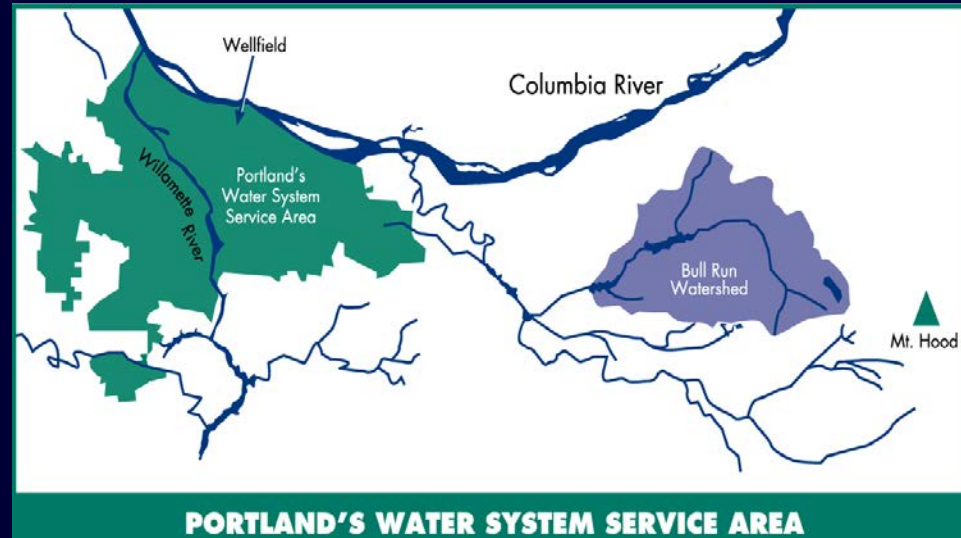
Conceptual Model

Coupling of Human and Environmental Systems



Bull Run Watershed

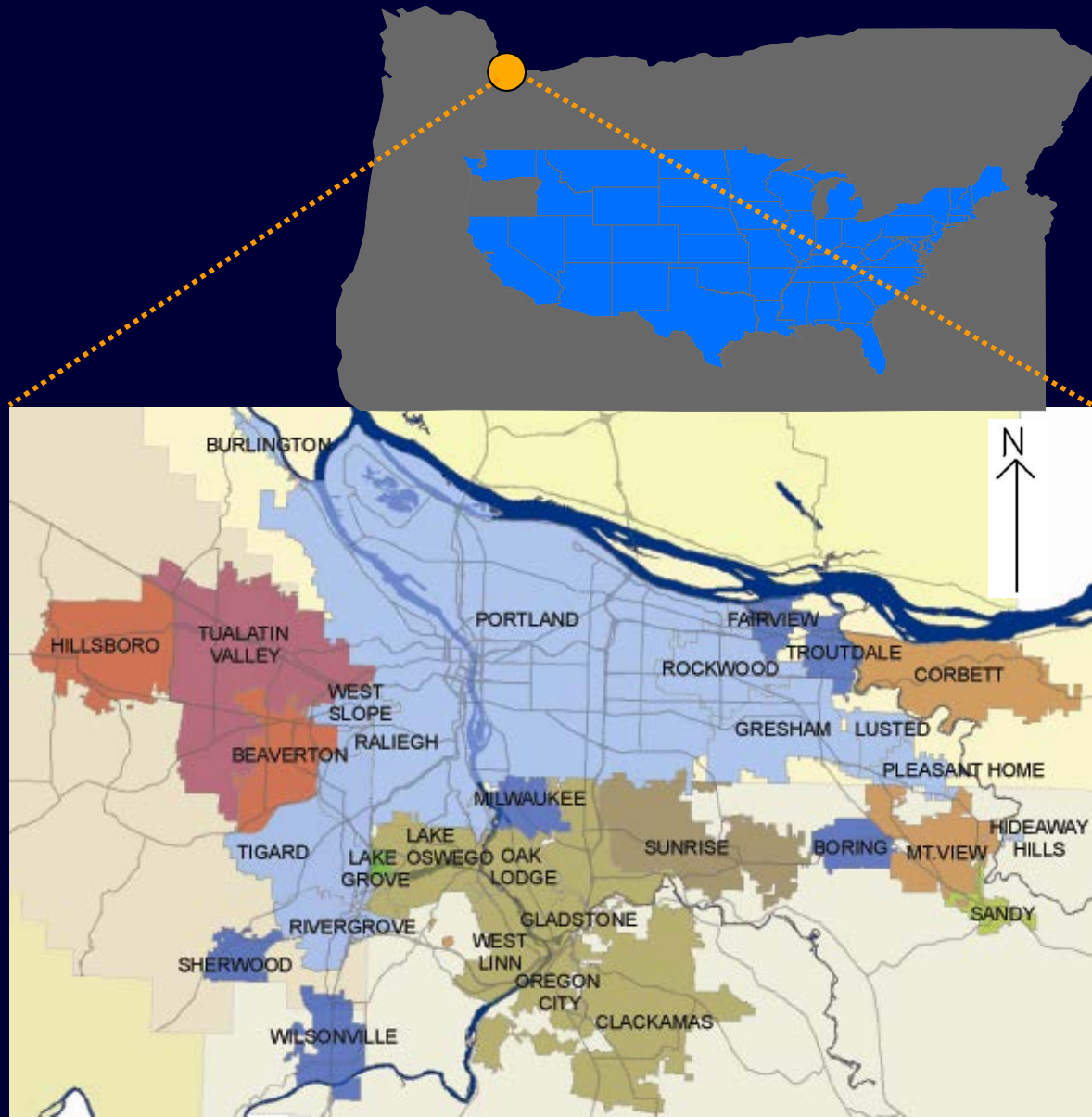
- Portland's planning policies:
 - No Requirement to ensure adequate water supply
- Goal 2, of the Portland's land-use plan identifies 'water' as an infrastructure subsystem
- Bull Run Watershed
 - 102 square miles, Cascade Snowmelt snowmelt
 - Started in January 1895 consisted



Case Study

Portland Water Bureau

- Serves 19 water providers of the region
- 802,000 residents served total, retail service 539,200
- This study focused on Portland's retail service area only
- 149,000 residential accounts
- 30,000 commercial and industrial accounts



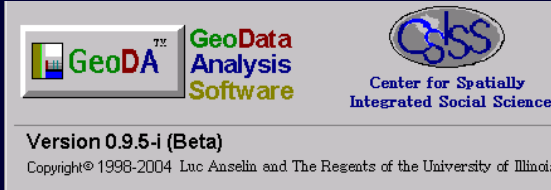
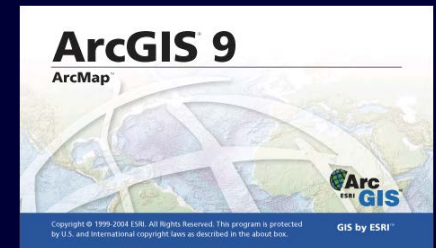
Data and Methods

- Water use (PWB)
 - (1) Yearly: for all taxlots (1999 – 2005)
 - (2) Daily: 501 SFR taxlots
- Land use (Metro)
 - Structural attributes, building age, address
- Daily temperature (OSU)
- Demographic data (US Census)
 - Income, education
- Aerial photos (City of Portland)
 - Canopy cover – parcel scale
- GIS and statistical methods
 - GIS: to integrate structural and societal characteristics
 - OLS, pooled-cross section, and hierarchal statistical models to assess relationships



Metro | *People places. Open spaces.*

U.S. Census Bureau



Version 0.9.5-i (Beta)

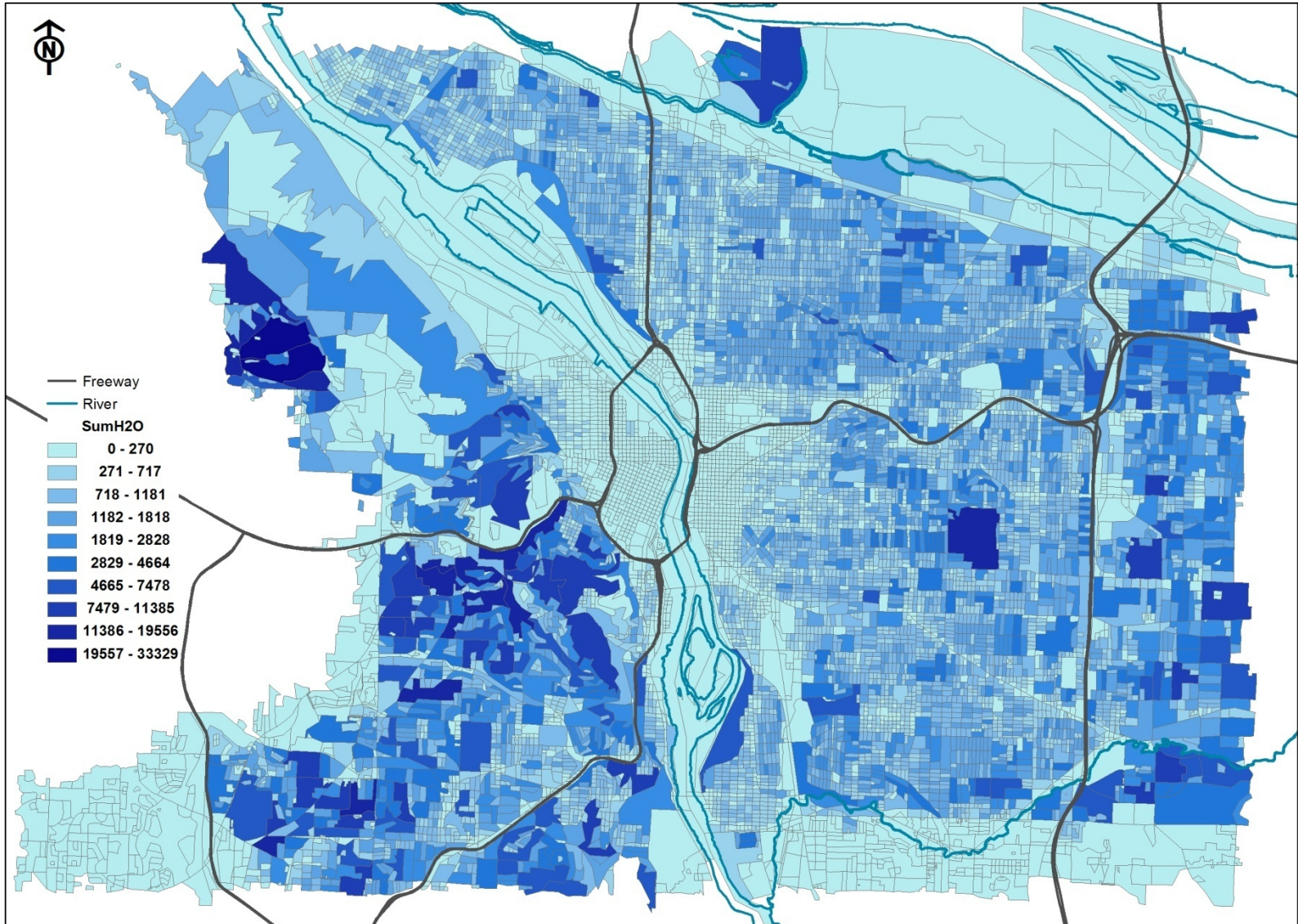
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Three Analysis to Address Objectives

- (1) Analysis of land use building area with annual water consumption
 - Provides evidence about the role of *land use planning* on water demand management
- (2) Analysis of residential and neighborhood development patterns and annual water consumption
 - Provides evidence about the role of *urban form* in water demand management
- (3) Analysis of historic and projected daily maximum temperatures with water use
 - Provides evidence about the *impact of climate change* on water demand management

Synthesis of Residential Water Use Data

Sum of Water Usage For Portland, OR Census Blocks

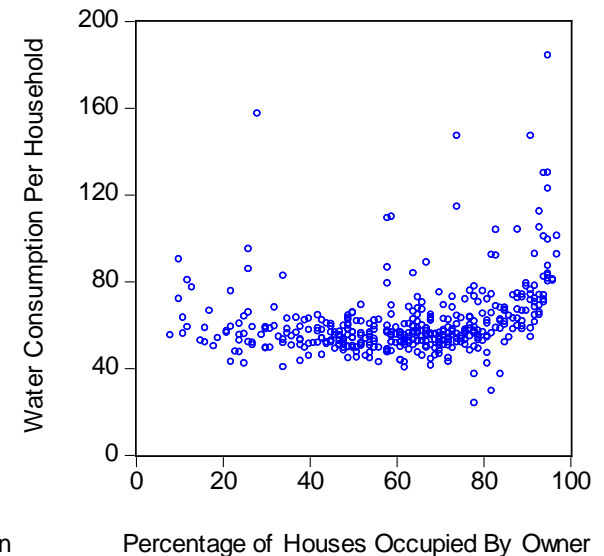
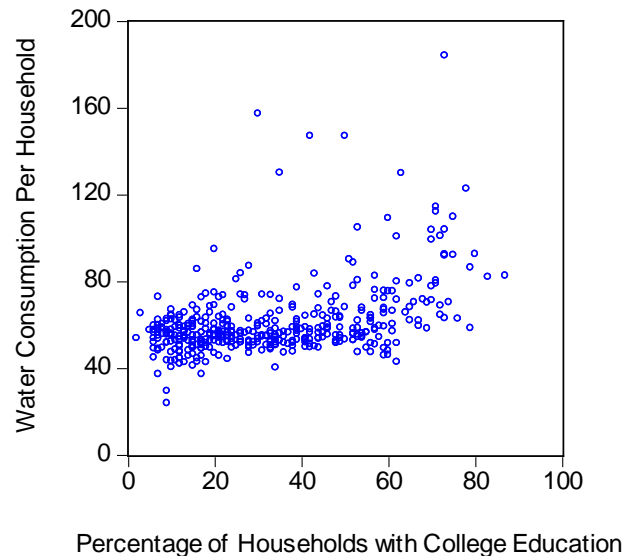
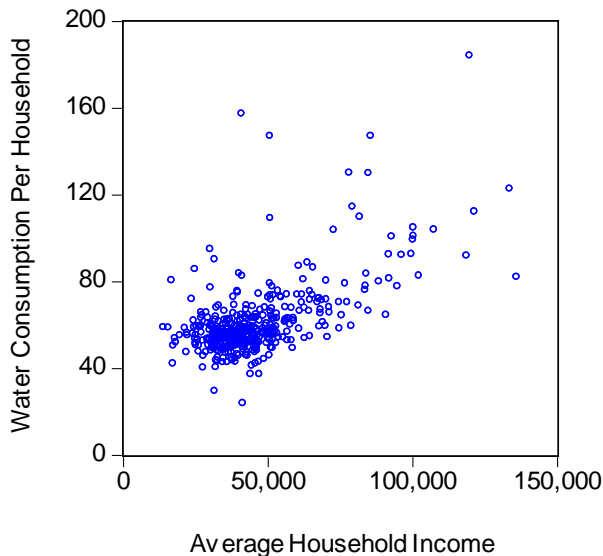
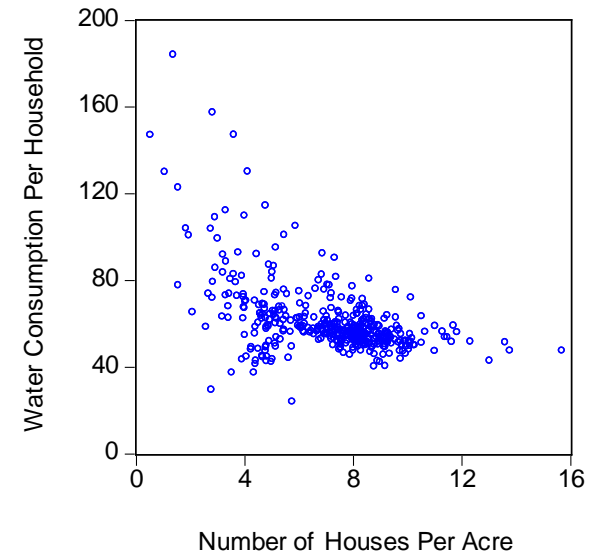
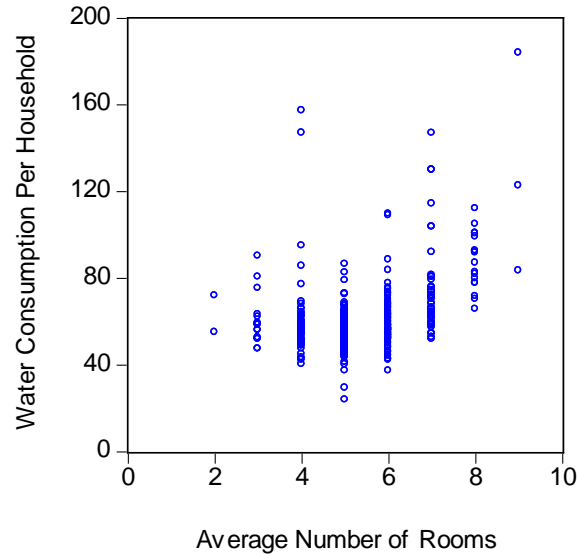
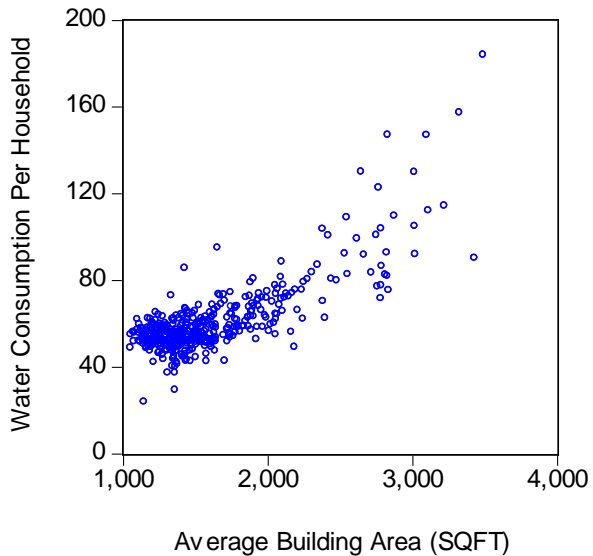


Results: Pooled Cross Section

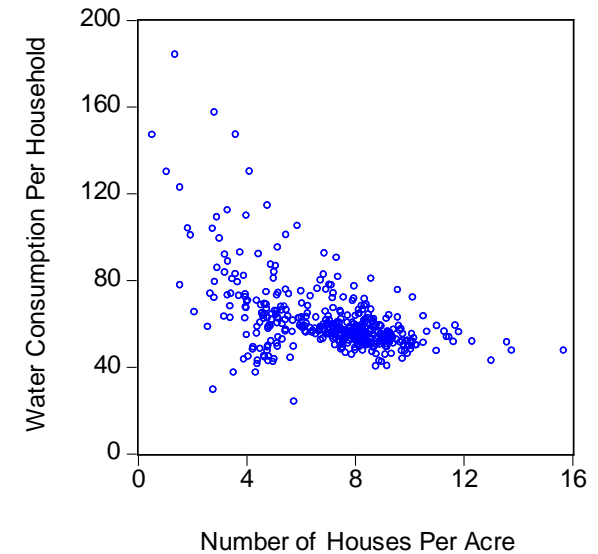
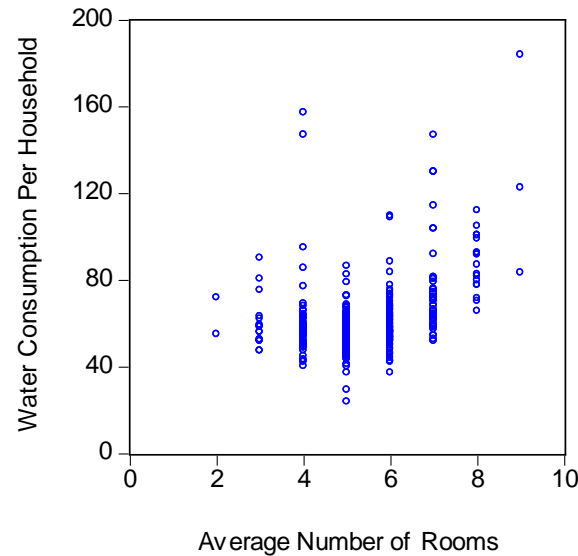
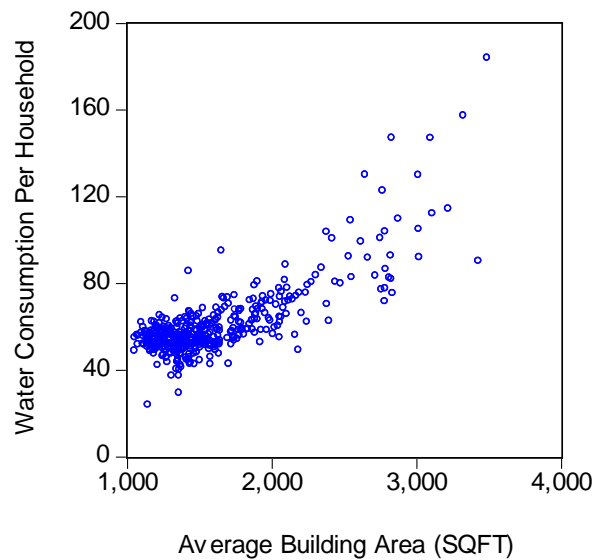
- Zoned and Building area
 - Overall explanatory power (R^2) is improved
 - Zoned area and building area coefficients vary
 - MFR and SFR have similar building area water use coefficients

Land Use Type	Coefficients			
	Zoned		Building Area	
Com_Ind_Acre	0.24	*	1.66	*
MFR_Acre	1.69	*	3.88	*
SFR_Acre	0.72	*	3.76	*
VAC_Acre	0.72		- 0.1 ^a	*
Model Adjusted R-Squared	0.84	*	0.93	*
<i>a = Zoned, not buliding area</i>				
<i>* = Significance < 0.05</i>				

Water Use: Structures & Demographics



Water Use: Residential Structures



Building Variable	Coefficient	Standard Error	T-Statistic
Constant	101.834	7.869	12.901
Building size (per 1000)	0.783	0.033	23.361
Density (hh/acre)	-4.904	1.01	-4.858
Years built (per year)	-0.171	0.109	-1.56

N = 398 block groups, $R^2 = 0.71$

All Significant at $P < 0.001$

High water use neighborhood

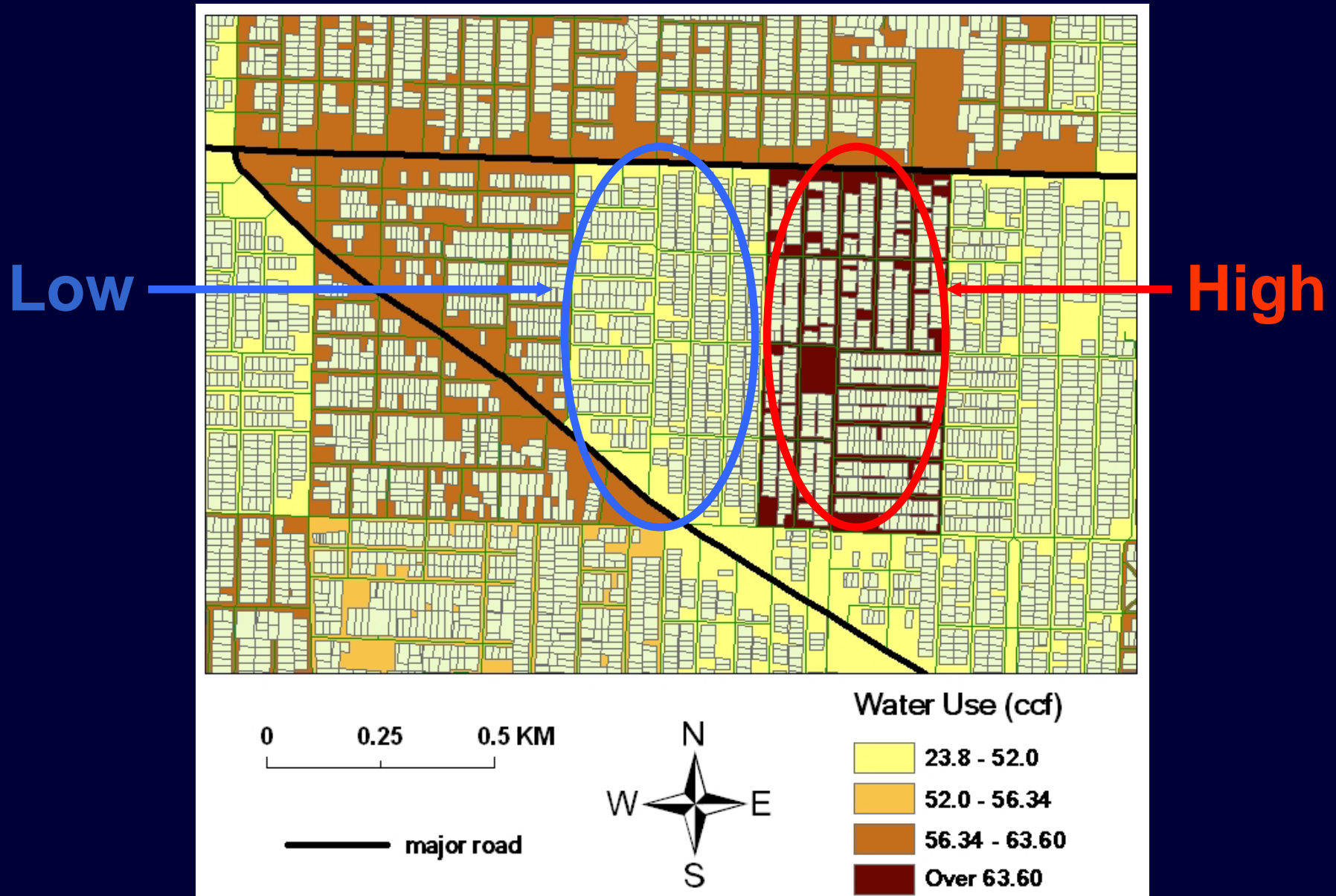


0 20 40 Meters

Low water use neighborhood



Parcel Level SFR Water Use





Low

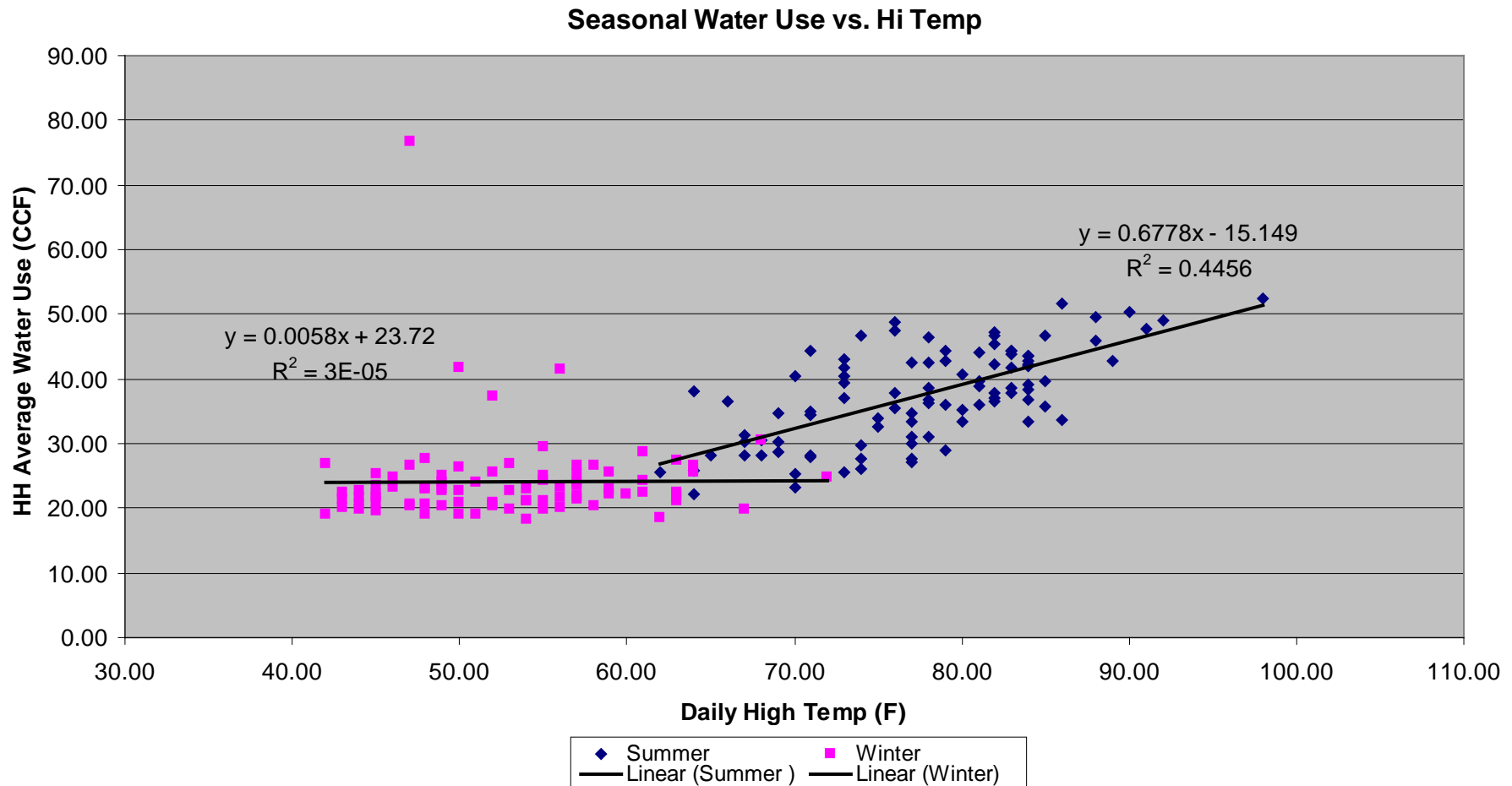


High

0 20 40 Meters

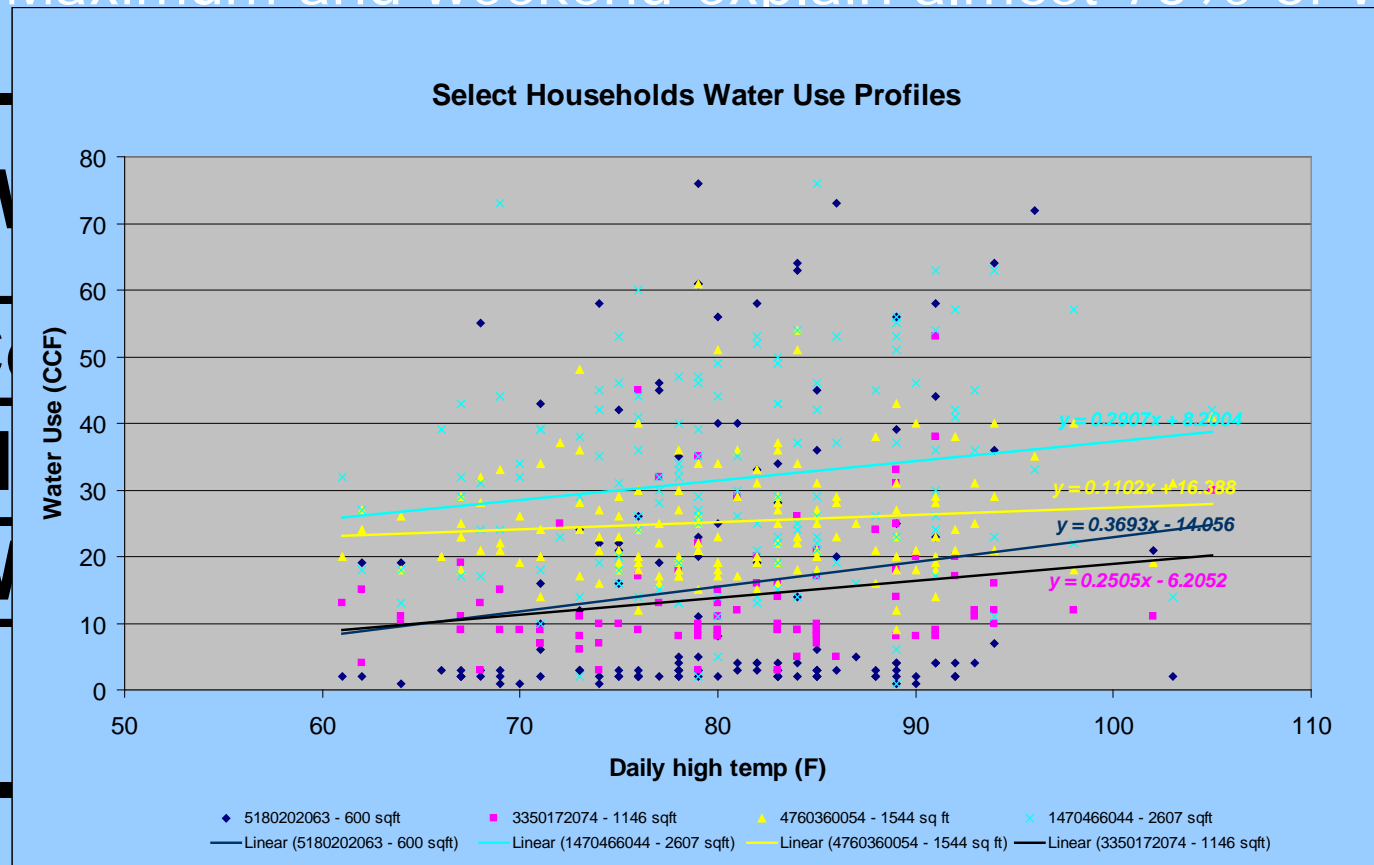
Results: Temperature Analysis 2

- Seasonal patterns are strong
 - Threshold increase in water use occurring at 69°F



Results: Temperature Analysis 1

- Temperature as predictors of water use
 - Noisy data linking temperature to water use
 - Water use becomes more varied as daily max temperatures rise
 - Maximum and weekend explain almost 75% of water use



Understanding Water Use Dynamics

Driver

Temperature
Maximum, Timing



Climate
Scenarios

Pattern

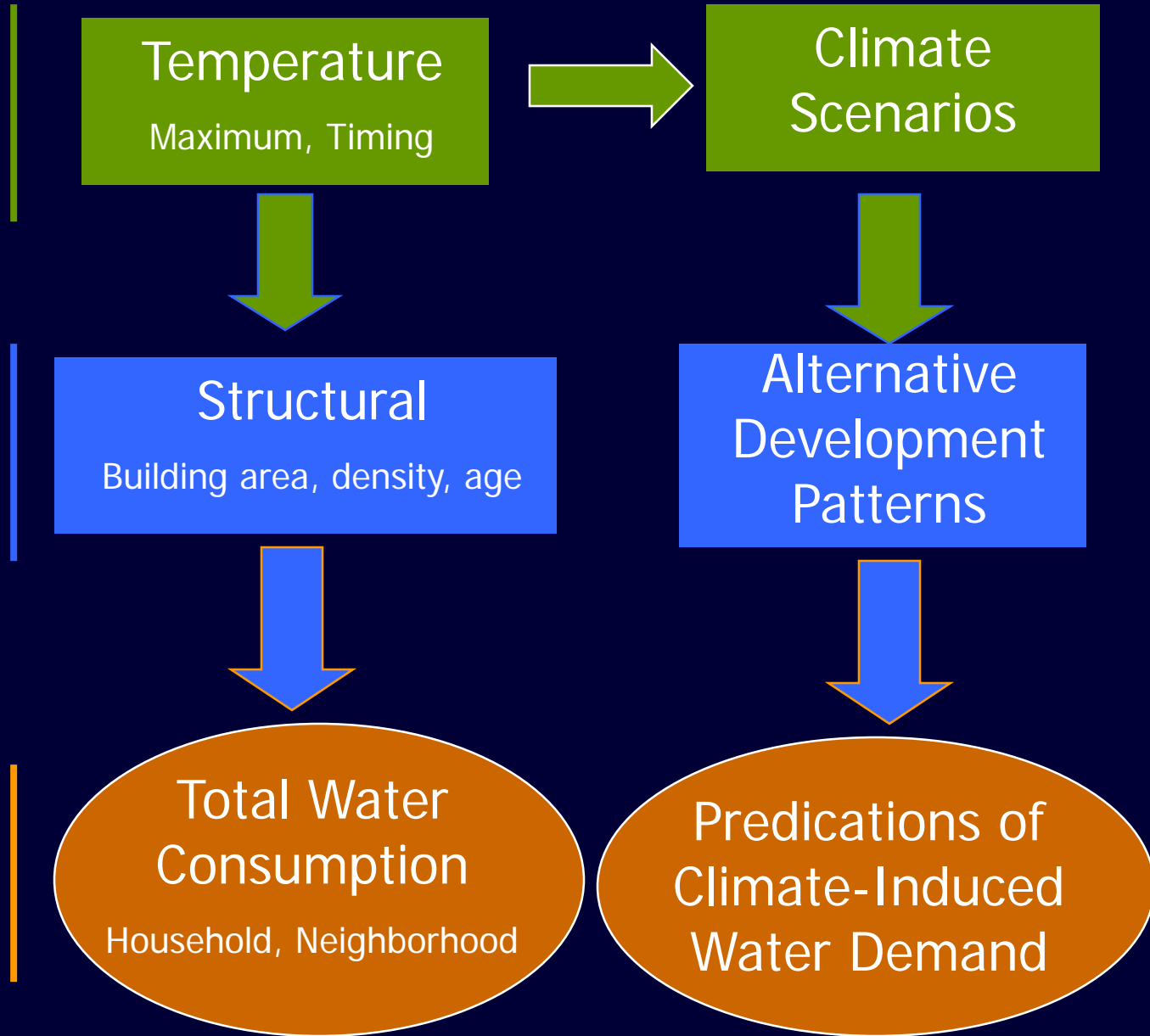
Structural
Building area, density, age

Alternative
Development
Patterns

Effect

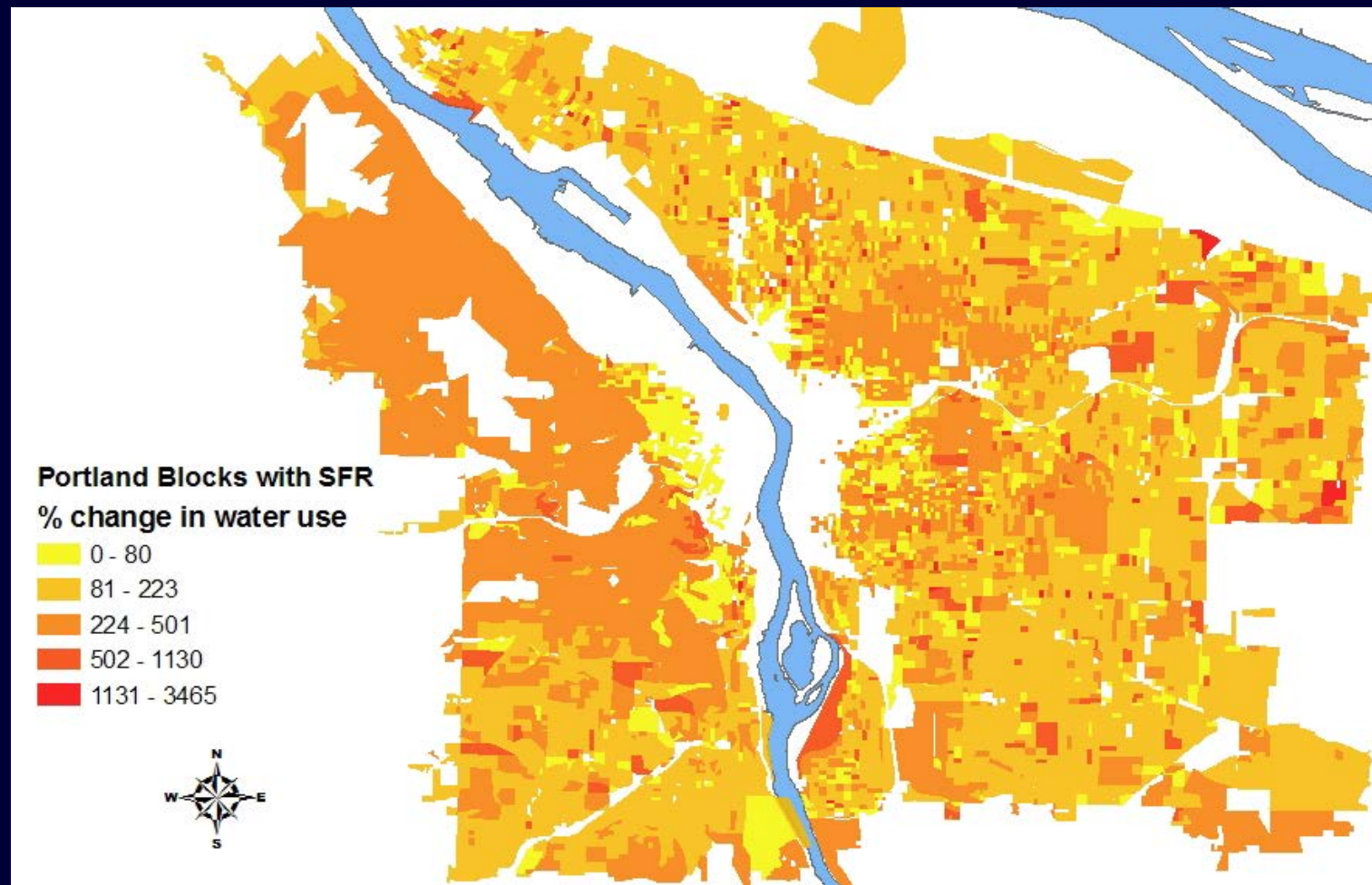
Total Water
Consumption
Household, Neighborhood

Predictions of
Climate-Induced
Water Demand



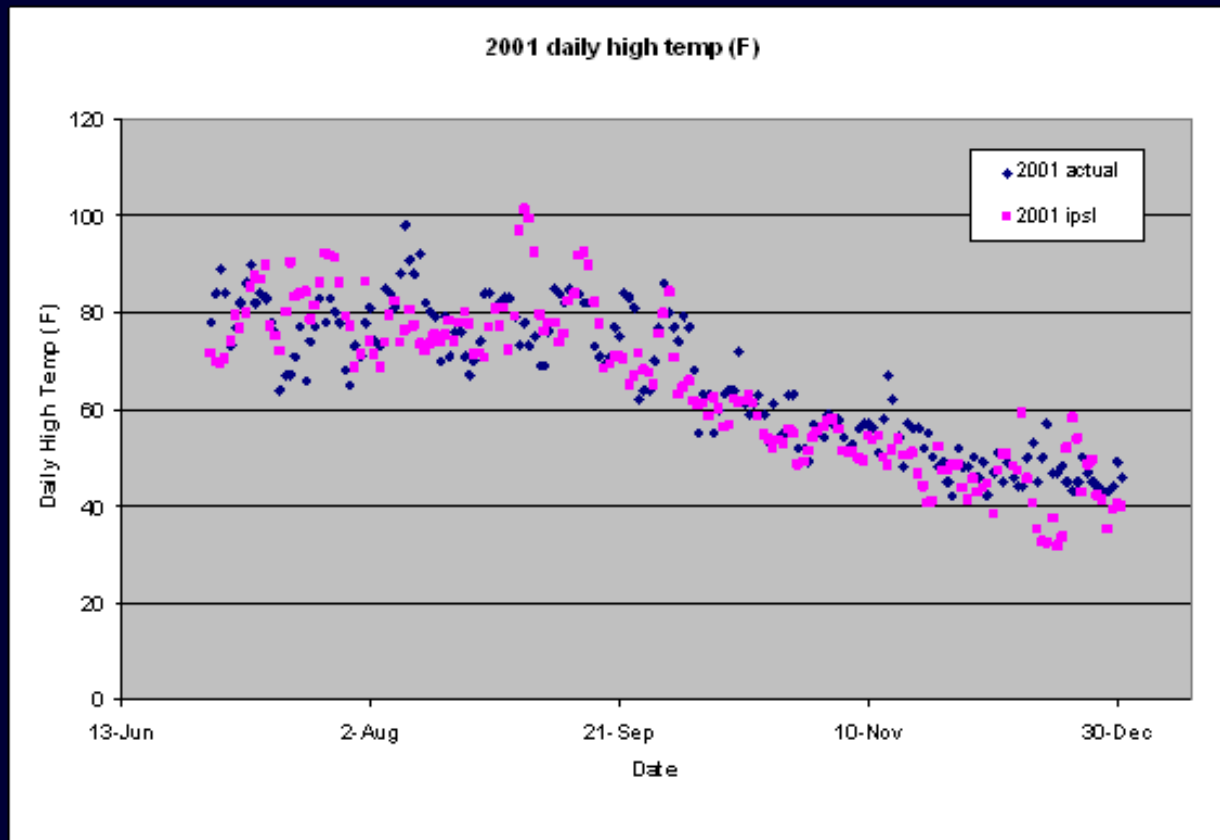
Seasonal Changes in Water Use

- Change in water use between coldest day and warmest day (*2001, census block geography*)



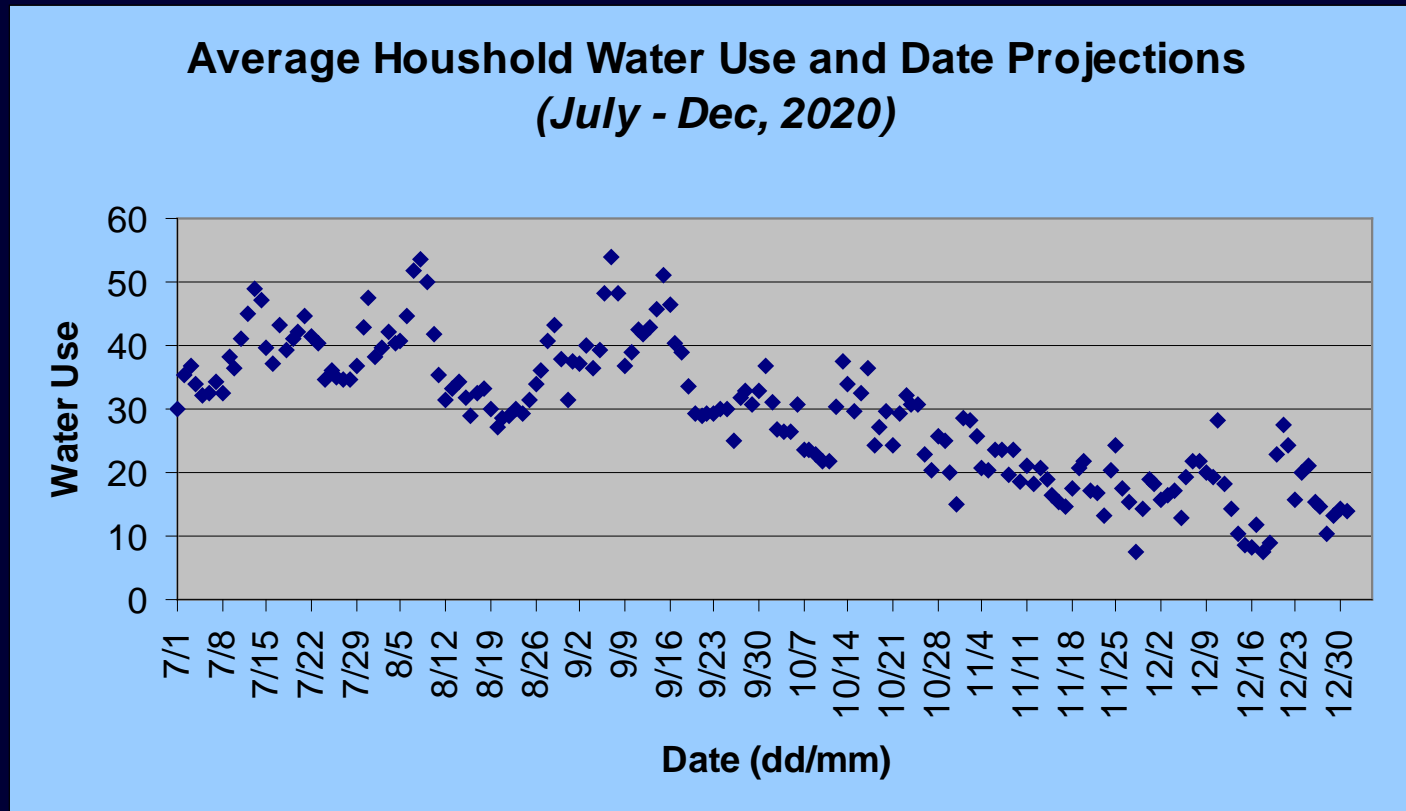
Future Climate Scenarios

- Climate Impact Group's IPSL_CM4 A2 used to examine model accuracy for 2001: suggest 98% accuracy



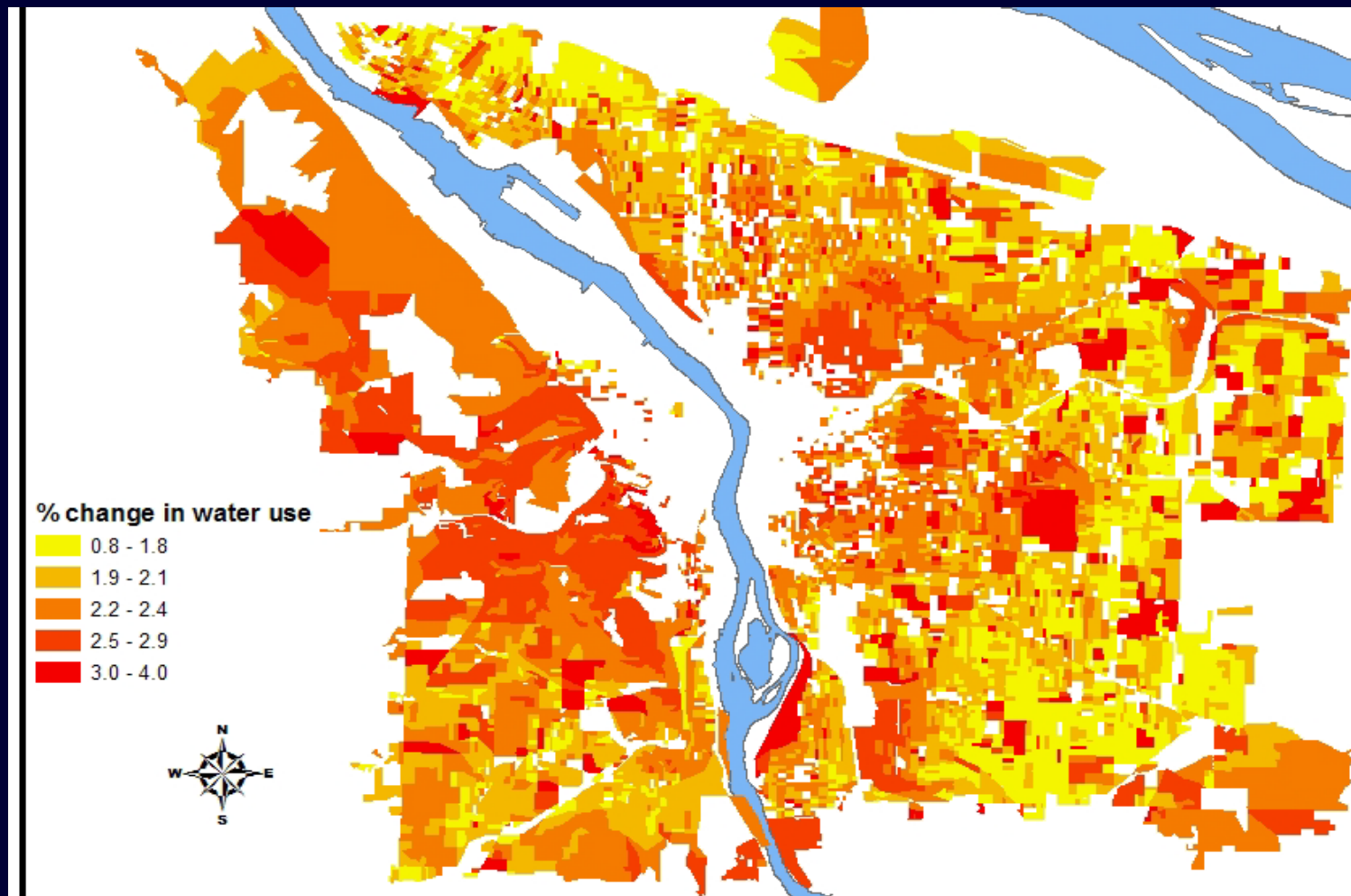
Future Climate Scenarios

- What is the potential change in SFR water use based on down-scaled climate models of the PNW?
 - Modeling water use (*based on predicted temperature*) through 2020



Forecasting Changes in Water Use

- Using only results from temperature data
 - Percent change in water use from 2001 – 2040 (IPSL)



Implications of Climate Change on Residential Water Use

- Scenario: An 80F day in a development containing 100 new houses (4K sqft)
 - For an average house (~ 2K square feet), each additional 1000 square feet of SFR house creates an additional water demand of 82 gallons
 - Compounded by temperature
 - These houses are about 2000 square feet larger than the average house in the Region, and 10 degrees above the 700F degree threshold.
 - The combined impact of this new development is approximately 20,900 gallons per day, which is approximately the amount of water stored in a typical household swimming pool
- The role of Land Use Planning
 - An additional 25% reduction in the average building size – a reduction from 2,800 ft² to 2,100 ft² in the study region –
 - Annual saving of 6.6 million gallons of water.
 - For a new residential development of 100 SFR units, annual decrease of 651 million gallons per year -- 1000 Olympic size swimming pools.

Implications of Coupling Water and Land Use

Management

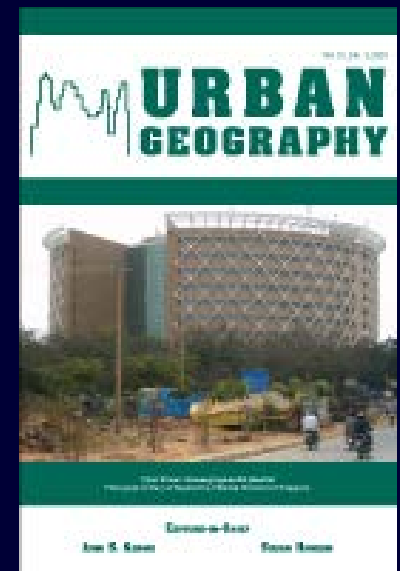
- Short term: Urban form, such as housing density and building size, need to be considered when planning for water demand.
- Long term: We need to develop mechanisms for better coordinating land and water use management, especially in the urban and urbanizing areas
- Linking climate-induced water demand with expected changes to water supplies will improve society's capacity for predicting future water needs

Research

- Develop models that link alternative urban land use patterns and temperature scenarios to predict differences in water demand
- Identify thresholds of population growth, land use patterns and temperature regimes that combine to
- Compare and contrast findings from Portland (OR) with other urban regions in the United States
- Collaborate with regional managers to identify and evaluate policies for better coordinating water and land use policies

Papers for Reference

- Shandas, V., and GH Parandvash (2009). Integrating Urban Form and Demographics in Water-Demand Management: An empirical case study of Portland, OR. *Environment and Planning B*, Vol 35 (1)
- Chang, H., GH Parandvash, and V Shandas (2010). Spatial Variations of Single Family Residential Water Use in Portland, Oregon, *Urban Geography*
- Shandas, V., M Rao, and MM McGrath (*under review*). The implications of climate change on residential water use: A micro-scale analysis of Portland (OR). *Journal of Water and Climate Change*



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